Ka-Band Objects: Observation and Monitoring Project

Advanced Exploration Systems Program | Human Exploration And Operations Mission Directorate (HEOMD)

ABSTRACT

NASA has embarked on a path to implement a high power, higher resolution radar system to:

•Track Near Earth Objects (NEOs)- asteroids and comets - 100,000 times more accurately than optical telescopes, as part of a system to defend the Earth from major impacts.

•Characterize the size, shape, spin rate, and surface properties of these NEOs to determine which are suitable for eventual visits by crews or mining companies.

•Track orbital debris to ensure crew and spacecraft safety.

The path to the high power radar will take evolutionary steps to lead to the revolutionary capability. The first step is KaBOOM.

ANTICIPATED BENEFITS

To NASA unfunded & planned missions:

High resolution tracking and characterization (size, shape, spin, porosity) of Near Earth Objects.

The Ka-band radar offers the possibility of high range resolution (5 cm) and high spatial resolution, also 5 cm for orbital debris in geosynchronous orbit (GEO) around the Earth (about 22,000 miles above the surface).

Planetary Defense: part of a plan to avoid impacts by asteroids and comets

To other government agencies:

Space Domain Awareness (SDA):

Detailed simulations of the capabilities of a phased array radar system indicates that current gaps in the following areas of SDA knowledge can be addressed

Ka-Band Objects: Observation and Monitoring Project: Current Array Configuration of Three 12m Reflector Antennas at the Kennedy

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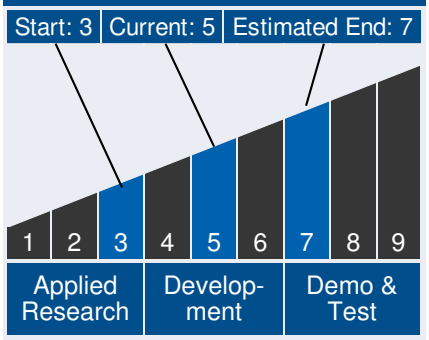
Technology Maturity



Management Team

Program Executive:

- Bernard Geldzahler

Program Manager:

- Jason Crusan

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Ka-Band Objects: Observation and Monitoring Project

- **Detect/Track/Identify**: Uncued detection, Unexpected maneuvers

  Discriminate between closely spaced objects

- **Characterization**: Orbital Debris, Satellite break-ups, collisions
- **Threat Warning and Assessment:** Conjunction assessment, Re-entry prediction

A Ka band system using coherent uplink arraying techniques and bistatic and multistatic radars can meet and probably exceed the goals or, at the very least, compliment a 90 GHz system. Specifically, at Ka-band range resolution of 5 cm and a spatial resolution (using a US-Australia baseline) of ~ 5 cm can be achieved.

To the commercial space industry:

The goal of KaBOOM is to prove technologies that will allow future systems to characterize Near Earth Objects in terms of size, shape, rotation/tumble rate and to determine the trajectory of those objects. Radar studies can determine the trajectory 100,000 times more precisely than can optical methods.

Current NASA radar systems are limited in both resolution and the distance at which they are effective. KaBOOM is the penultimate, low-cost step before proceeding with a high-power, high-resolution radar system.

For geolocation applications, measurement of atmospheric fluctuations coupled with other sensor data has the potential to increase the accuracy and precision of ground-based target location.

For space communication purposes, the wider spectrum allocation (10x wider than at X-band) will allow for more data to be sent at a given time.

For radio science, the 100-1000x increase in possible uplink power will allow for more precise determination of planetary

Management Team *(cont.)*

Project Manager:
- Robert Brown

Principal Investigator:
- Bernard Geldzahler

Co-Investigators:
- Melanie Ott
- Jason Soloff

Technology Areas

Primary Technology Area:
Communications, Navigation, and Orbital Debris Tracking and Characterization Systems (TA 5)
└ Radio Frequency Communications (TA 5.2)
└ Antennas (TA 5.2.6)
└ Phased Array Antennas (TA 5.2.6.2)

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properties.

To the nation:

The ultimate goal of a future implemented radar system is to obtain images of NEOs to see details as small as 5 cm in size (about the size of a golf ball). Today, NASA's best radar images are limited to 400 cm (about the size of a bedroom). Knowing what an asteroid looks like and its characteristics is crucial to the safety of a crewed mission to that asteroid or to determine if the asteroid might hit and damage the Earth.

DETAILED DESCRIPTION

NASA is pursuing a demonstration of coherent uplink arraying at 7.145-7.190 GHz (X-band) and 30-31 GHz (Ka-band) using three 12m diameter commercial off-the-shelf (COTS) antennas separated by 60m at the Kennedy Space Center in Florida. In addition, the Agency has demonstrated uplink arraying using up to three 34m antennas separated by ~250m at the Goldstone Deep Space Communication Complex in California and at X-band 7.1 GHz incorporating *real-time correction for tropospheric phase fluctuations*. Such a successful demonstration would then enable NASA to design and establish a high power, high resolution, 24/7 availability radar system for

(a) tracking and characterizing observations of Near Earth Objects,

(b) tracking, characterizing and determining the statistics of small-scale (≤10cm) orbital debris,

(c) incorporating the capability into the Agency's space communication and navigation tracking stations for emergency spacecraft commanding in the Ka-band era that NASA is entering, and

(d) fielding capabilities of interest to other US government agencies.

The Ka-band radar offers the possibility of high range resolution

Technology Areas *(cont.)*

Additional Technology Areas:
Communications, Navigation, and Orbital Debris Tracking and Characterization Systems (TA 5)
- Radio Frequency Communications (TA 5.2)
  - Antennas (TA 5.2.6)
    - Atmospheric Phase Compensation for Uplink Arrays at Ka-Band (TA 5.2.6.3)
- Position, Navigation, and Timing (TA 5.4)
- Orbital Debris Tracking and Characterization (TA 5.7)
  - Tracking Technologies (TA 5.7.1)
    - Ka-Band Objects Observation and Monitoring (TA 5.7.1.2)

(5 cm) and high spatial resolution, also 5 cm for orbital debris in geosynchronous orbit (GEO) around the Earth (about 22,000 miles above the surface). The project will consist of three phases or evolutionary steps that will lead to the new revolutionary capability. The beginning is KaBOOM.

KaBOOM: Space communication system at 8 and 30 GHz, currently in development at Kennedy Space Center, as the prelude to a high power radar array. Will demonstrate phased array uplink of widely spaced antennas with real time compensation for atmospheric phase fluctuations.

KARNAC (Ka band Array Radar for NEO Accurate Characterization): KaBOOM will be transformed to a phased array radar demonstration facility. Each antenna will have a transmitter of 25 kW peak power in the 34-36 GHz range. The total combined uplink power will be ~ 225 kW.

SOAR (Space Object Array Radar): Large element operational phased array radar (15 – 100 transmitter elements) for both at X and Ka-band high precision tracking, imaging and characterization of near Earth objects and orbital debris. Each antenna will have 100 kW of transmit power with a bandwidth of 4 GHz centered on a frequency of 35 GHz, yielding a range resolution of 5 cm.

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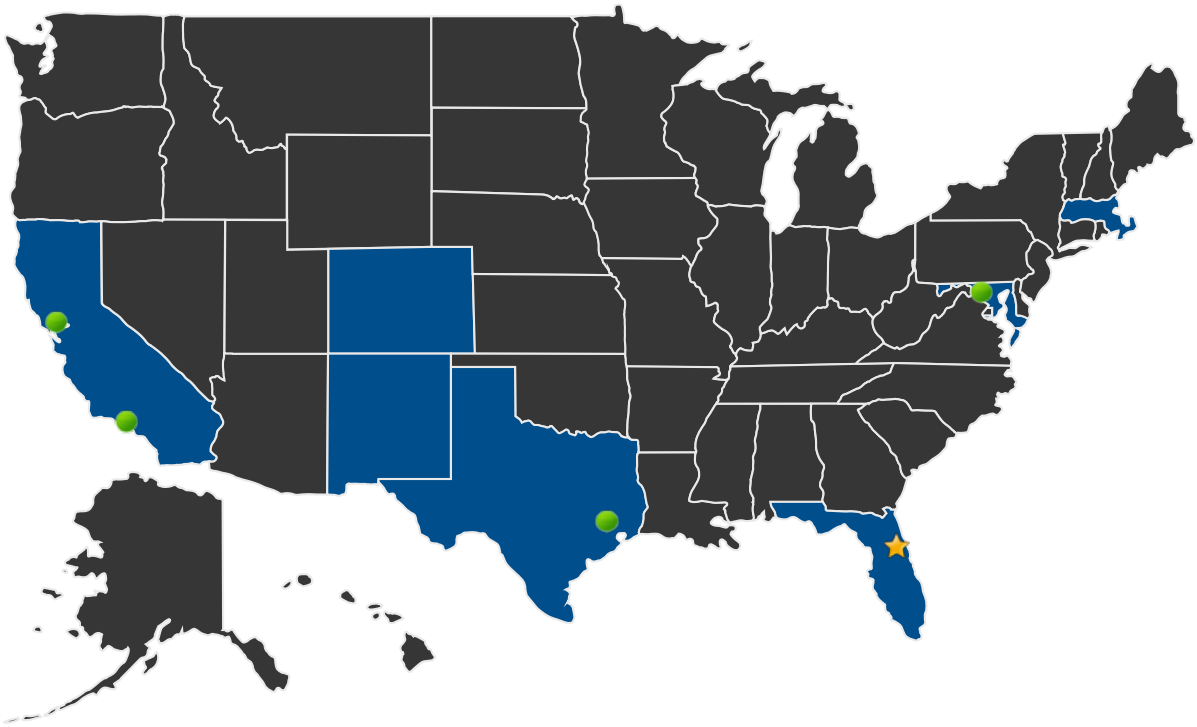
U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
Kennedy Space Center

Supporting Centers:

- Ames Research Center
- Goddard Space Flight Center
- Jet Propulsion Laboratory
- Johnson Space Center

Other Organizations Performing Work:

- JHU Applied Physics Laboratory
- MIT LINCOLN LABORATORY
- Sandia National Laboratory

IMAGE GALLERY

Ka-Band Objects: Observation and Monitoring Project: During Construction

DETAILS FOR TECHNOLOGY 1

Technology Title

Ka-Band Objects: Observation and Monitoring (KaBOOM)

Technology Description

This technology is categorized as a hardware system for ground support or mission operations

With the successful completion (Feb 2015) of a field demonstration of uplink arraying at 8 GHz (X-band) with a phased array of widely separated antennas in a space communications mode using real-time atmospheric compensation enabled by phase transfer rather than time transfer techniques, NASA is pursuing a similar demonstration of the capability at 30-31 GHz (Ka-band).

Capabilities Provided

In Development and Demonstration

•Low life-cycle cost radio frequency communication at 8 and 30 GHz and radar system at 33-37 GHz

•Phased array of widely-spaced, commercial off-the-shelf antennas.

•Algorithms that correct for atmospheric twinkling in real-time to maximize the projected power after the signals from each antenna are combined.

•High precision radar imaging using Ka-band frequencies to see features as small as 5 cm.

•Available 24/7 for Near Earth Object (NEO) and orbital debris characterization

•Scalable options to enable the deployment of a large element array that includes the capability to be upgraded to a larger network of antennas designed to track asteroids and determine how close to Earth they will come.

Potential Applications

KaBOOM is a Ka-band coherent uplink arraying proof of concept demonstration being undertaken to allow a decision to be made for implementing an envisioned National Radar Facility [large scale arrays(s)] for the following applications:

- High power, high resolution radar system
- Space Domain Awareness
- 24/7 availability for near Earth objects (NEOs) and orbital debris tracking and characterization
- High resolution mapping of water in discrete locations on the moon
- Mapping radar stealth zones on Mars to help define "no drive" zones for future rovers to avoid the Spirit problem
- Power beam sailing propulsion capability